Mac OS X Color Image Management Explained

Session 209

These are confidential sessions—please refrain from filming or taking pictures.

Graphics and Media

Mac OS X Color Image Management Explained

David Hayward
Software Engineer

http://developer.apple.com/wwdc2005/

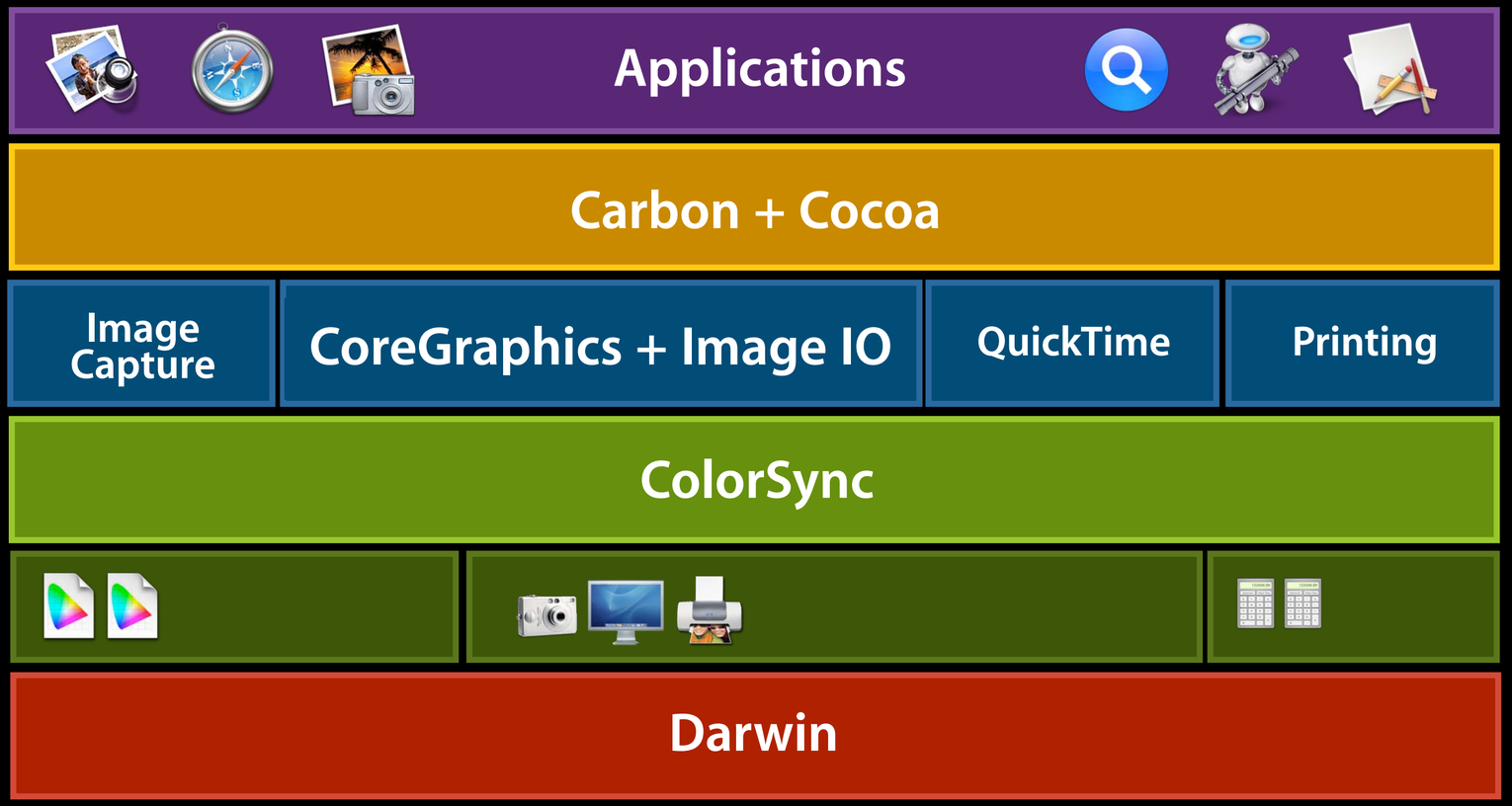
Introduction

- Architectural Overview
- Opening Images with Image IO
- Displaying Images
- Filtering Images with Core Image
- Printing Images
- Saving Images with Image IO

Architectural Overview

http://developer.apple.com/wwdc2005/

Architectural Overview



API Data Types for Color Management

	Color Space	Bitmap Image	Spot Color
Cocoa	NSColorSpace	NSBitmapImageRep	NSColor
Quartz	CGColorSpace	CGImage	CGColor
ColorSync	CMProfile	CMBitmap	CMColor

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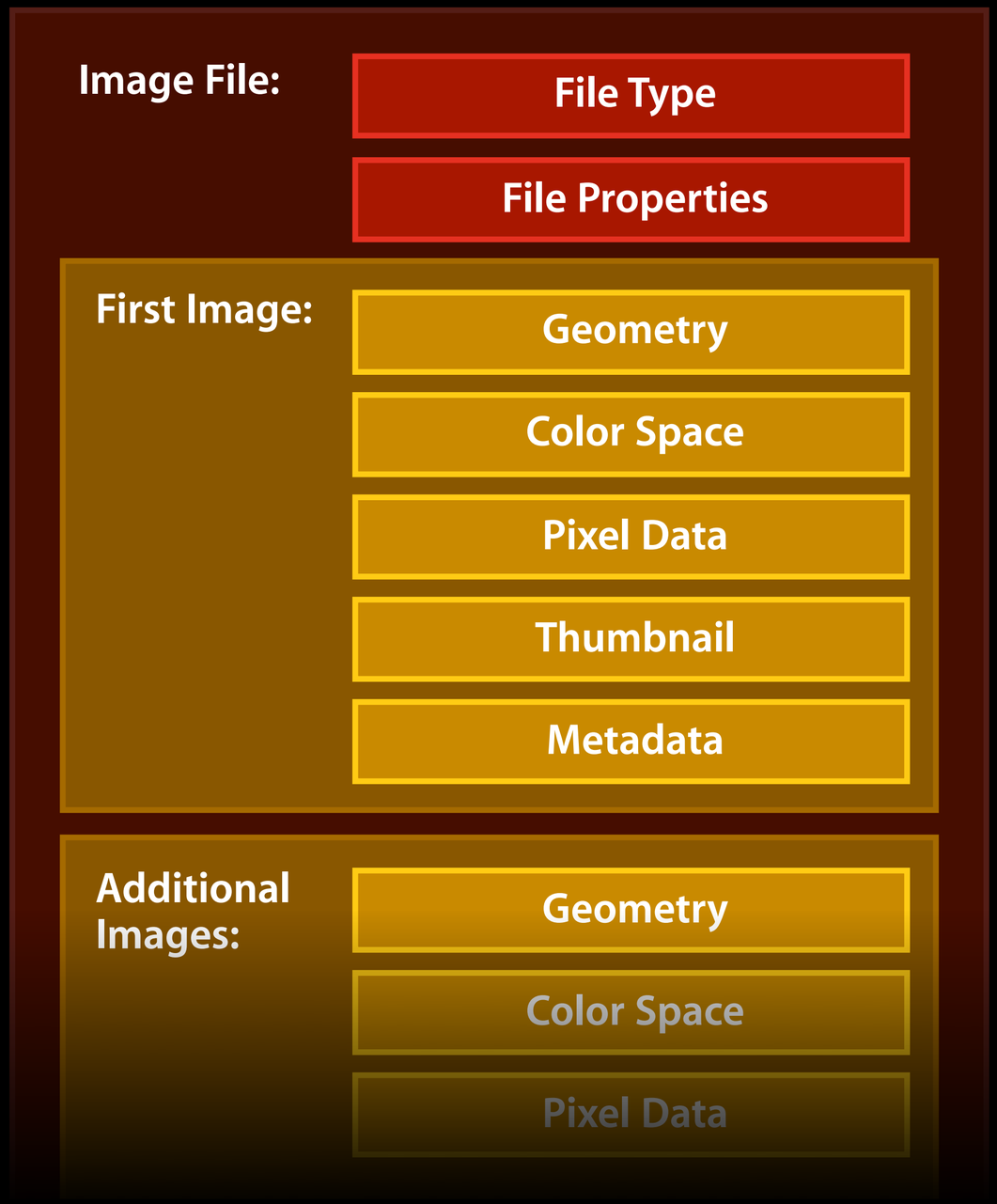
Image IO Features

- Read many file formats
- Write to file formats
- Read and write metadata
- Incremental loading
- Floating point support
- Automatic Color Management

Image IO Supported Formats

- Web standards
  - TIFF, JPEG, PNG, GIF, JPEG-2000
- Floating Point HDR formats
  - OpenEXR, Radiance, LogLuv TIFF, Float TIFF, and Pixar TIFF
- Camera Raw formats
  - Canon, Nikon, Minolta, Olympus, Sony
- Others
  - .bmp, .psd, .qtif, .tga, .sgi, .xbm, .icns, .ico, .pict, .ptng, .fpx
- Metadata
  - Exif, IPTC, CIFF, GPS, some MakerNotes, …
- More to come…

What's in an Image File



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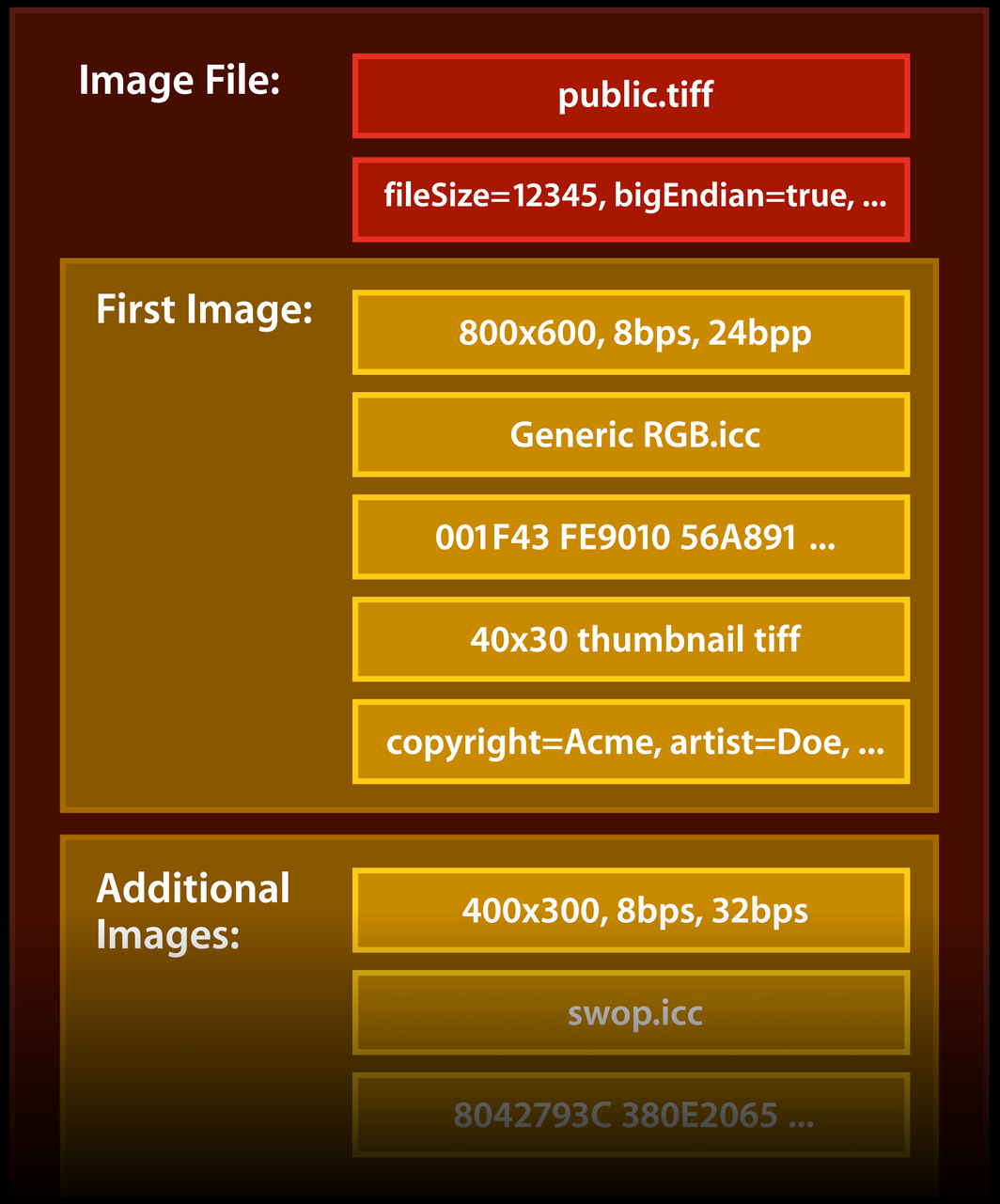

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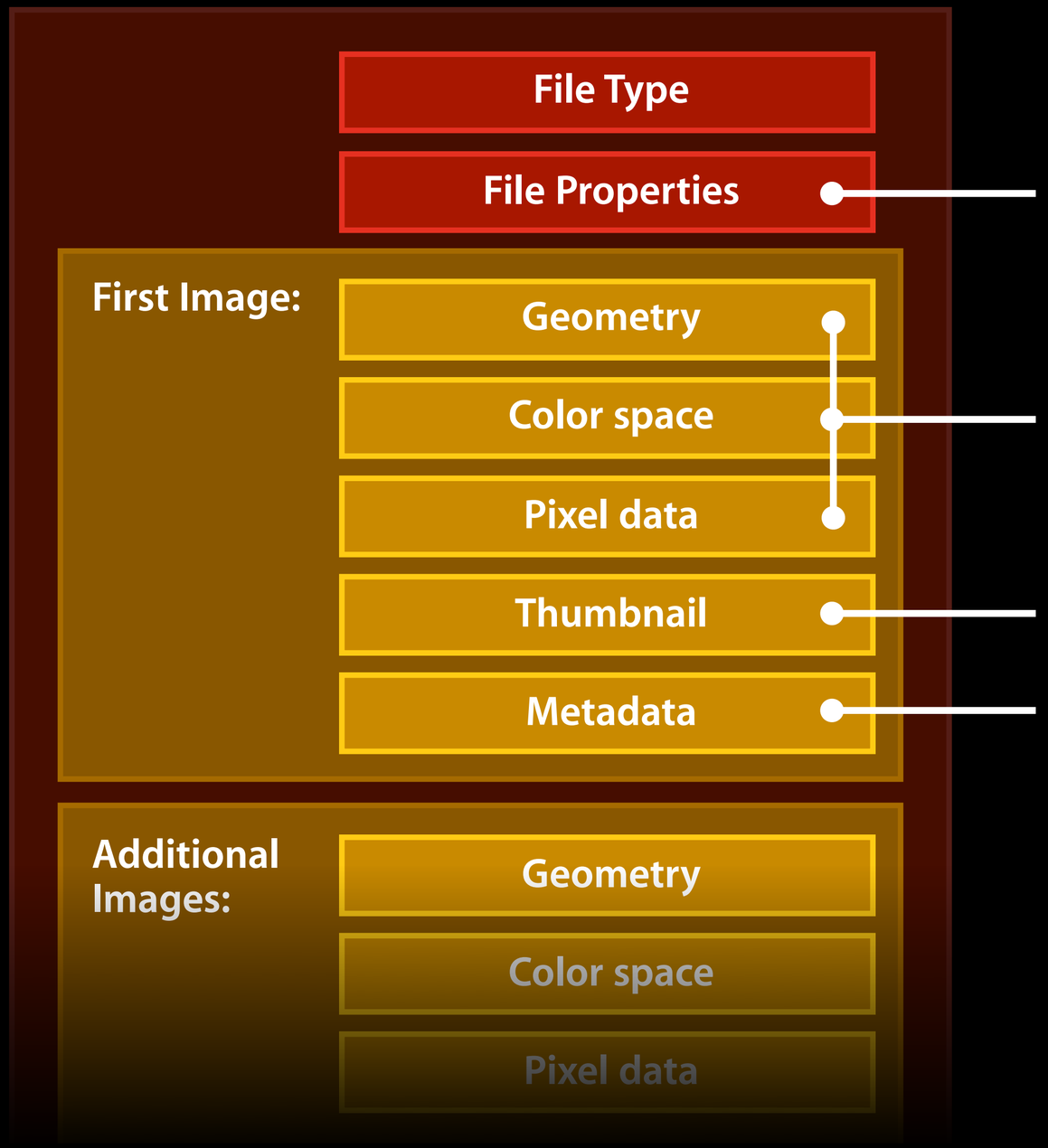
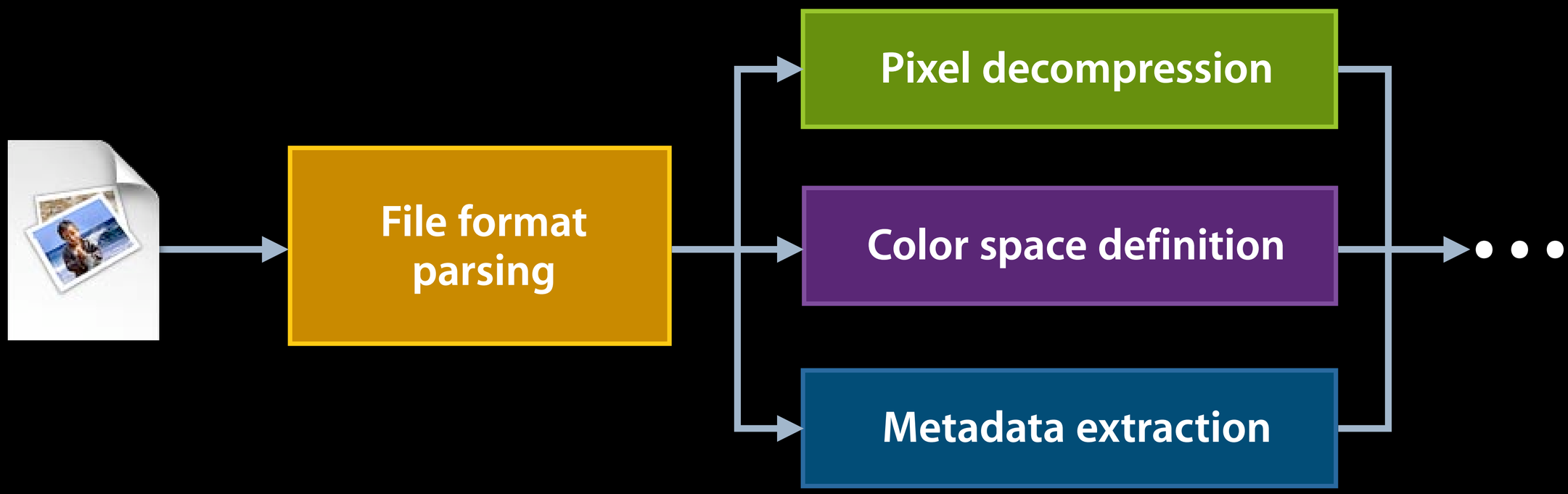


Opening Images With Image IO

http://developer.apple.com/wwdc2005/

Reading Digital Images

General steps when loading an image



Opening Images With Image IO

Basics

- Create a CGImageSource
  - Use `CGImageSourceCreateWithURL`
    or `CGImageSourceCreateWithData`
    or `CGImageSourceCreateWithDataProvider`
- Get Image Properties
  - Type identifier: `CGImageSourceGetType`
  - Image count: `CGImageSourceGetCount`
- For each
  - Get image: `CGImageSourceCreateImageAtIndex`
  - Get metadata: `CGImageSourceCopyPropertiesAtIndex`
  - Get thumb: `CGImageSourceCreateThumbnailAtIndex`

Opening Images With Image IO

CGImageSource image and metadata

```
CGImageRef GetFirstImage (CFURLRef url, float* xdpi, float* ydpi, int* orientation)
{
   CGImageSourceRef isrc = CGImageSourceCreateWithURL(url, nil);

   CFDictionaryRef props = CGImageSourceCopyPropertiesAtIndex(isrc,0,nil);
   CFNumberRef val;

   val = CFDictionaryGetValue(props, kCGImagePropertyDPIWidth);
   if (val) CFNumberGetValue(val, kCFNumberFloatType, xdpi);

   val = CFDictionaryGetValue(props, kCGImagePropertyDPIHeight);
   if (val) CFNumberGetValue(val, kCFNumberFloatType, ydpi);

   val = CFDictionaryGetValue(props, kCGImagePropertyOrientation);
   if (val) CFNumberGetValue(val, kCFNumberIntType, orientation);

   return CGImageSourceCreateImageAtIndex(isrc, 0, nil);
}
```

Opening Images With Image IO

CGImageSource thumbnail

```
CGImageRef GetFirstThumb (CFURLRef url)
{
   CGImageSourceRef isrc = CGImageSourceCreateWithURL(url, nil);

   CFStringRef keys[2]; CFTypeRef vals[2];

   keys[0] = kCGImageSourceCreateThumbnailFromImageIfAbsent;
   vals[0] = kCFBooleanTrue;

   keys[1] = kCGImageSourceThumbnailMaxPixelSize;
   vals[1] = CreateIntNumber(160);

   CFDictionaryRef opts = CFDictionaryCreate(nil, keys, values, 2,
       &kCFCopyStringDictionaryKeyCallBacks, &kCFTypeDictionaryValueCallBacks);

   return CGImageSourceCreateThumbnailAtIndex(isrc, 0, opts);
}
```

Opening Images With Image IO

Advanced Techniques

- Loading Images Incrementally
- Reading Floating Point HDR Images
- Dynamic support for all Image IO readable types

Opening Images: Advanced Techniques

Loading an image incrementally

```
void DrawFirstImageIncrementally (CFURLRef url)
{
   CGImageSourceRef isrc = CGImageSourceCreateIncremental(nil);
   do {
       bool       done;
       CFDataRef  data = GetAccumulatedDataSoFar(&done)

       CGImageSourceUpdateData(isrc, data, done);

       CGImageRef img = CGImageSourceCreateImageAtIndex(isrc, 0, nil);
       CGImageSourceStatus status = CGImageSourceGetStatusAtIndex(isrc, 0);
       if (img) {
           DrawImage(img);
           CFRelease(img);
       }
   } while (done==false && status!=kCGImageStatusComplete);
}
```

Opening Images: Advanced Techniques

Reading floating point images

- Some file formats support only one pixel depth
  - e.g. a JPEG file is always 8 bits per sample
- Some file formats support several pixel depths
  - e.g. a TIFF file can be 1,2,4,8, or 16 bits per sample

- As a rule, a CGImageRef returned by Image IO will be the same depth as the file

Opening Images: Advanced Techniques

Reading floating point images

- HDR files are a bit more complicated
  - The data in the file is typically specially packed
  - There are often several methods to unpack the bits
    - Unpacked to floats (32 or 16) or integers (16 or 8)
    - Unpacked to extended range (<0 .. >1) or compressed (0..1)

- By default, the CGImageRef returned by Image IO will be compressed to a 16bit integers
- By request, the CGImageRef can be returned as extended range floats

Opening Images: Advanced Techniques

Reading floating point images

```
CGImageRef GetFirstImageFloat (CFURLRef url, Boolean* isFloat)
{
   CGImageSourceRef isrc = CGImageSourceCreateWithURL(url, nil);

   CFStringRef keys[1] = { kCGImageSourceShouldAllowFloat };
   CFTypeRef values[1] = { kCFBooleanTrue };

   CFDictionaryRef opts = CFDictionaryCreate(nil, keys, values, 1,
       &kCFCopyStringDictionaryKeyCallBacks, &kCFTypeDictionaryValueCallBacks);

   CFDictionaryRef props = CGImageSourceCopyPropertiesAtIndex(isrc,0,opts);

   *isFloat = CFDictionaryContainsKey(props, kCGImagePropertyIsFloat);

   return CGImageSourceCreateImageAtIndex(isrc, 0, opts);
}
```

Opening Images: Advanced Techniques

Dynamic support for all Image IO readable types

- Get array of Image IO readable types: `CGImageSourceCopyTypeIdentifiers`
- Use `UTTypeCopyDeclaration` to get extensions of each readable type

ImageApp Sample Code

http://developer.apple.com/wwdc2005/

Displaying Images

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Software Engineer

http://developer.apple.com/wwdc2005/

Displaying Digital Images

General steps when displaying an image

Drawing Images in Quartz

CGContextDrawImage call

```
void CGContextDrawImage(
   CGContextRef context, // The graphics context in which to draw the image.
   CGRect       rect,    // The location and dimensions in user space of the
                         // bounding box in which to draw the image.
   CGImageRef   image    // The image to draw.
);
```

Quartz Graphics Context

The abstract for a drawing destination

- Contains drawing parameters and all device-specific information
- Can represent a window, a bitmap, an OpenGL surface, a PDF document, or a PostScript document

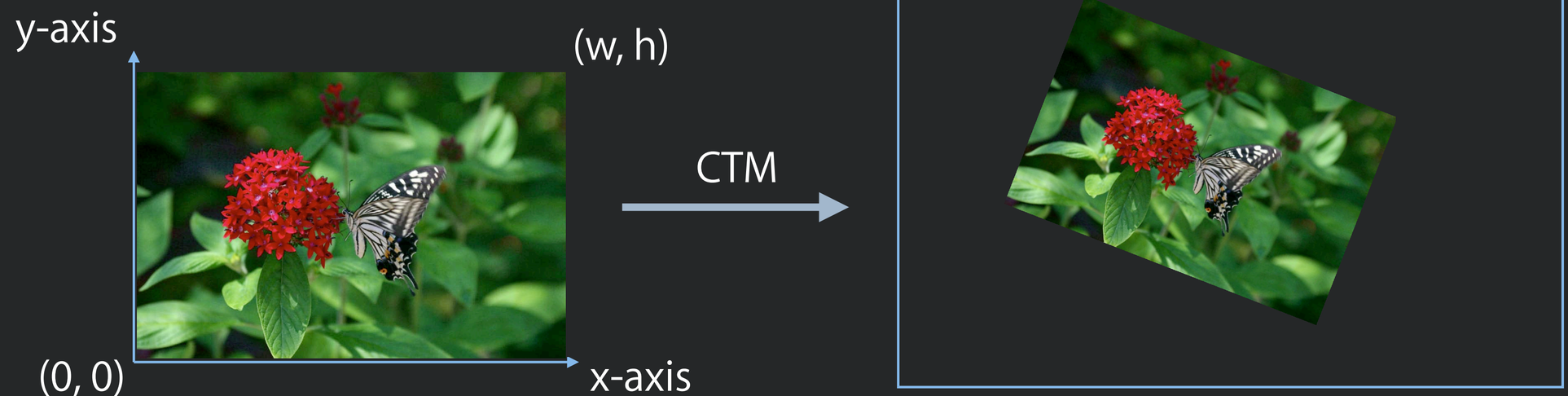
See “Quartz 2D Programming Guide” for more details

Drawing Images in Quartz

Quartz 2D Coordinates

User Space
w = image width
h = image height

Device Space
w′ = window context width
h′ = window context height



Drawing Images in Quartz

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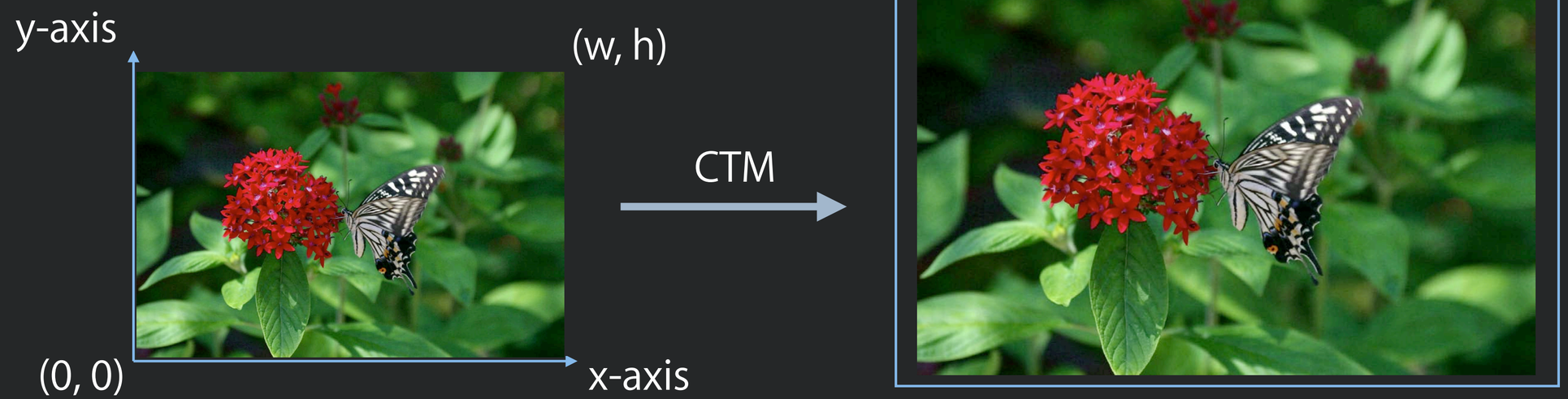


Drawing in a Cocoa NSView

Using the CGContextRef of a NSView

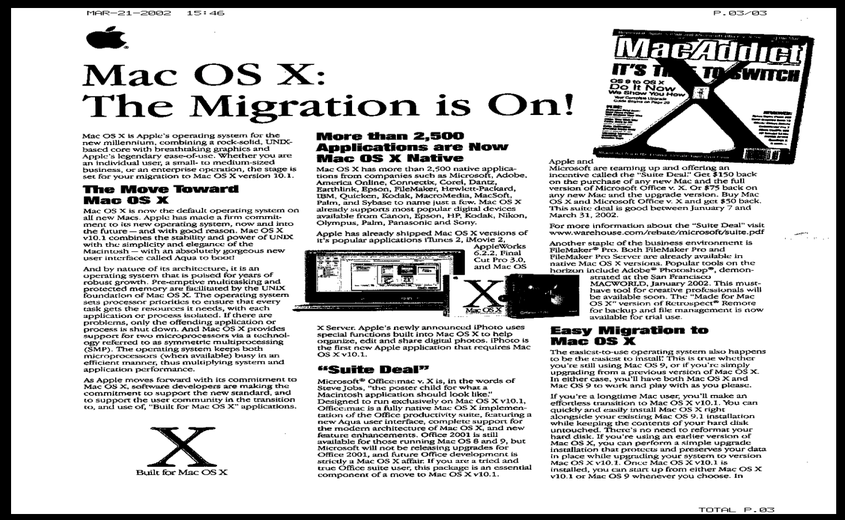
```
- (void) drawRect:(NSRect)rect
{
   CGContextRef context = [[NSGraphicsContext currentContext] graphicsPort];

   size_t w = CGImageGetWidth(mImage)
   size_t h = CGImageGetHeight(mImage);

   CGRect rect = {{0,0},{w,h}};

   CGAffineTransform ctm = [self imageTransformForView];

   CGContextConcatCTM(context, ctm);

   CGContextDrawImage(context, imageRect, mImage);
}
```

Drawing Images With Quartz

Image orientation

Drawing Images With Quartz

Aspect ratio



Drawing Images With Quartz

Respecting image orientation and aspect ratio

```
- (CGAffineTransform) imageTransform {
   float x = ([self dpiH]>[self dpiW]) ? [self dpiH]/[self dpiW] : 1;
   float y = ([self dpiW]>[self dpiH]) ? [self dpiW]/[self dpiH] : 1;
   float w = x * CGImageGetWidth(mImage), h = y * CGImageGetHeight(mImage);

   CGAffineTransform ctms[8] = {
      { x, 0, 0, y, 0, 0},  // 1 = normal
      {-x, 0, 0, y, w, 0},  // 2 = flip horizontal
      {-x, 0, 0,-y, w, h},  // 3 = rotate 180
      { x, 0, 0,-y, 0, h},  // 4 = flip vertical
      { 0,-x,-y, 0, h, w},  // 5 = rot -90, flip vert
      { 0,-x, y, 0, 0, w},  // 6 = rot 90
      { 0, x, y, 0, 0, 0},  // 7 = rot 90, flip vert
      { 0, x,-y, 0, h, 0}}; // 8 = rotate -90

   return ctms[[self orientation]-1];
}
```

Drawing Images: Advanced Techniques

- Extracting ARGB data from an image
- Assigning Default Profiles
- Finding a ColorSync profile for a NSWindow
- Matching across multiple displays
- NSWindowScreenChanged notification

Drawing Images: Advanced Techniques

Extracting ARGB from an image

```
void* GetImageAsARGB (CGImageRef image)
{
   size_t w = CGImageGetWidth(image)
   size_t h = CGImageGetHeight(image);
   CGRect rect = {{0,0},{w,h}};
   void* data = calloc(w*4,h);

   CGColorSpaceRef cs = CGColorSpaceCreateWithName(kCGColorSpaceGenericRGB);

   CGContextRef cgctx = CGBitmapContextCreate(data, w, h,
          8, w*4, cs, kCGImageAlphaPremultipliedFirst);

   CGContextDrawImage(cgctx, rect, image);

   CGColorSpaceRelease(cs);
   CGContextRelease(cgctx);
   return data;
}
```

Drawing Images: Advanced Techniques

Assigning default profiles

```
CGImageRef CopyImageWithDefaultProfile (CGImageRef image) {
   CGColorSpaceRef default = NULL, space = CGImageGetColorSpace (image);
   CGColorSpaceRef gray = CGColorSpaceCreateDeviceGray();
   CGColorSpaceRef rgb = CGColorSpaceCreateDeviceRGB();
   CGColorSpaceRef cmyk = CGColorSpaceCreateDeviceCMYK();
   CGImageRef copy = NULL;

   if (CFEqual (space, gray))      default = mDefaultGray;
   else if (CFEqual (space, rgb))  default = mDefaultRGB;
   else if (CFEqual (space, cmyk)) default = mDefaultCMYK;

   if (default)
       copy = CGImageCreateCopyWithColorSpace(image, default);
   else
       copy = CGImageRetain(image);

   CGColorSpaceRelease(gray); CGColorSpaceRelease(rgb); CGColorSpaceRelease(cmyk);
   return copy;
}
```

Drawing Images: Advanced Techniques

Finding a ColorSync profile for a NSWindow

```
- (CMDisplayIDType) displayID
{
   NSDictionary* d = [[[self window] screen] deviceDescription];
   return (CMDisplayIDType)[[d objectForKey:@"NSScreenNumber"] longValue];
}

- (CMProfileRef) displayProfile
{
   CMProfileRef prof;
   CMGetProfileByAVID([self displayID], &prof);
   return prof;
}

- (CGColorSpaceRef) displayColorSpace
{
   CMProfileRef prof = [self displayProfile];
   CGColorSpaceRef space = CGColorSpaceCreateWithPlatformColorSpace(prof);
   CMCloseProfile(prof);
   return space;
}
```

Drawing Images: Advanced Techniques

Matching across multiple displays

```
- (id) initWithFrame:(NSRect)frameRect
{
   [super initWithFrame:frameRect];

   [[self window] setDisplaysWhenScreenProfileChanges:YES];

   return self;
}
```

Drawing Images: Advanced Techniques

NSWindowDidChangeScreenProfileNotification

```
- (id) initWithFrame:(NSRect)frameRect
{
   [super initWithFrame:frameRect];

   [[self window] setDisplaysWhenScreenProfileChanges:YES];

   [[NSNotificationCenter defaultCenter]
      addObserver: self selector: @selector(newScreenProfile:)
             name: NSWindowDidChangeScreenProfileNotification object:nil];

   return self;
}

- (void) newScreenProfile:(NSNotification*)n
{
   // Do what you wanted to do when the display profile changes
}
```

ImageApp Demo

http://developer.apple.com/wwdc2005/

Filtering Images With Core Image

http://developer.apple.com/wwdc2005/

Drawing Images With Core Image

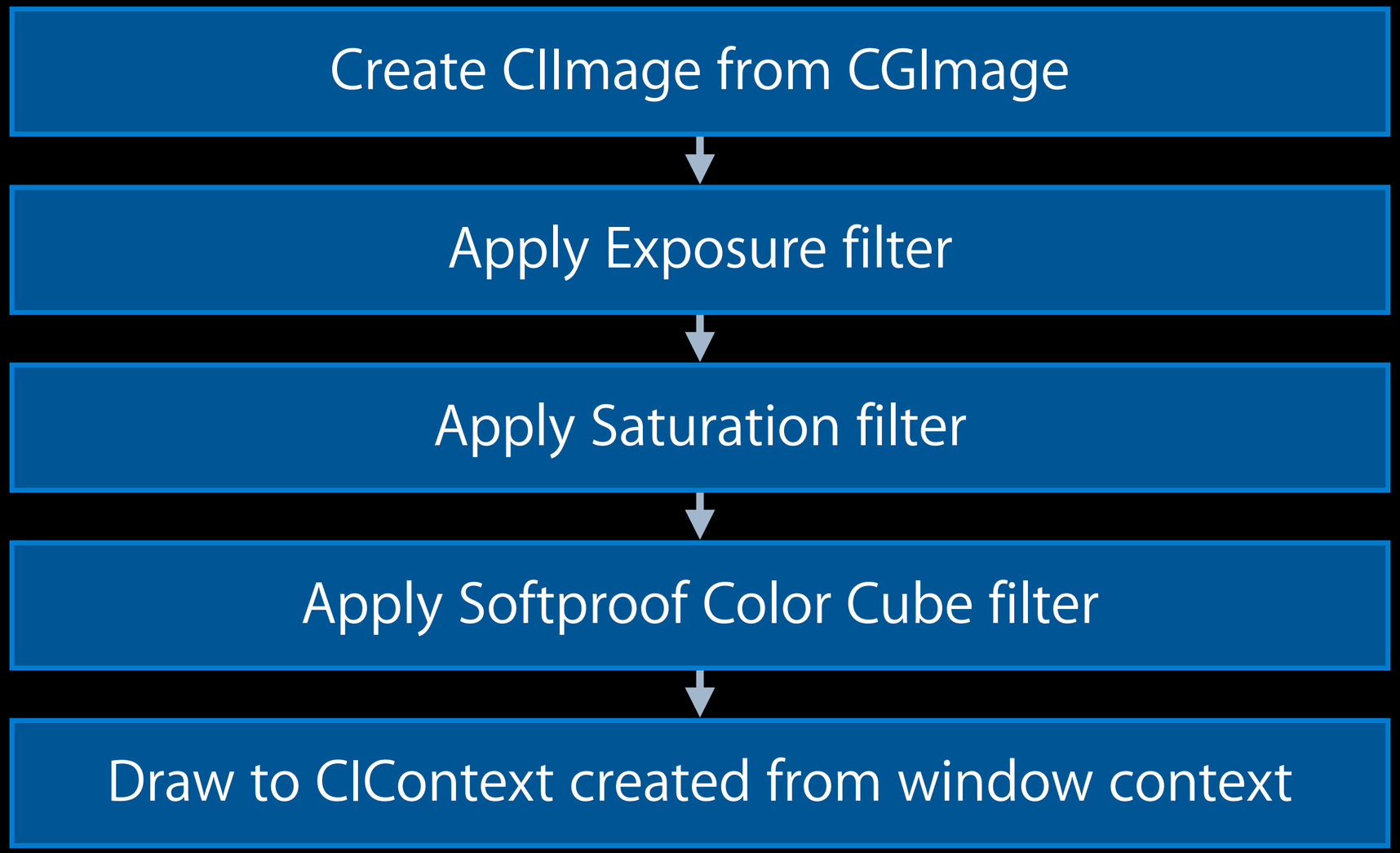
Basics

- Creating a CIImage from a CGImage
- Setting up and applying one or more CIFilters
- Creating a CIContext
- Drawing the result

See “Core Image Programming Guide” for more details

Filtering Images With Core Image

Drawing a filtered image to a window



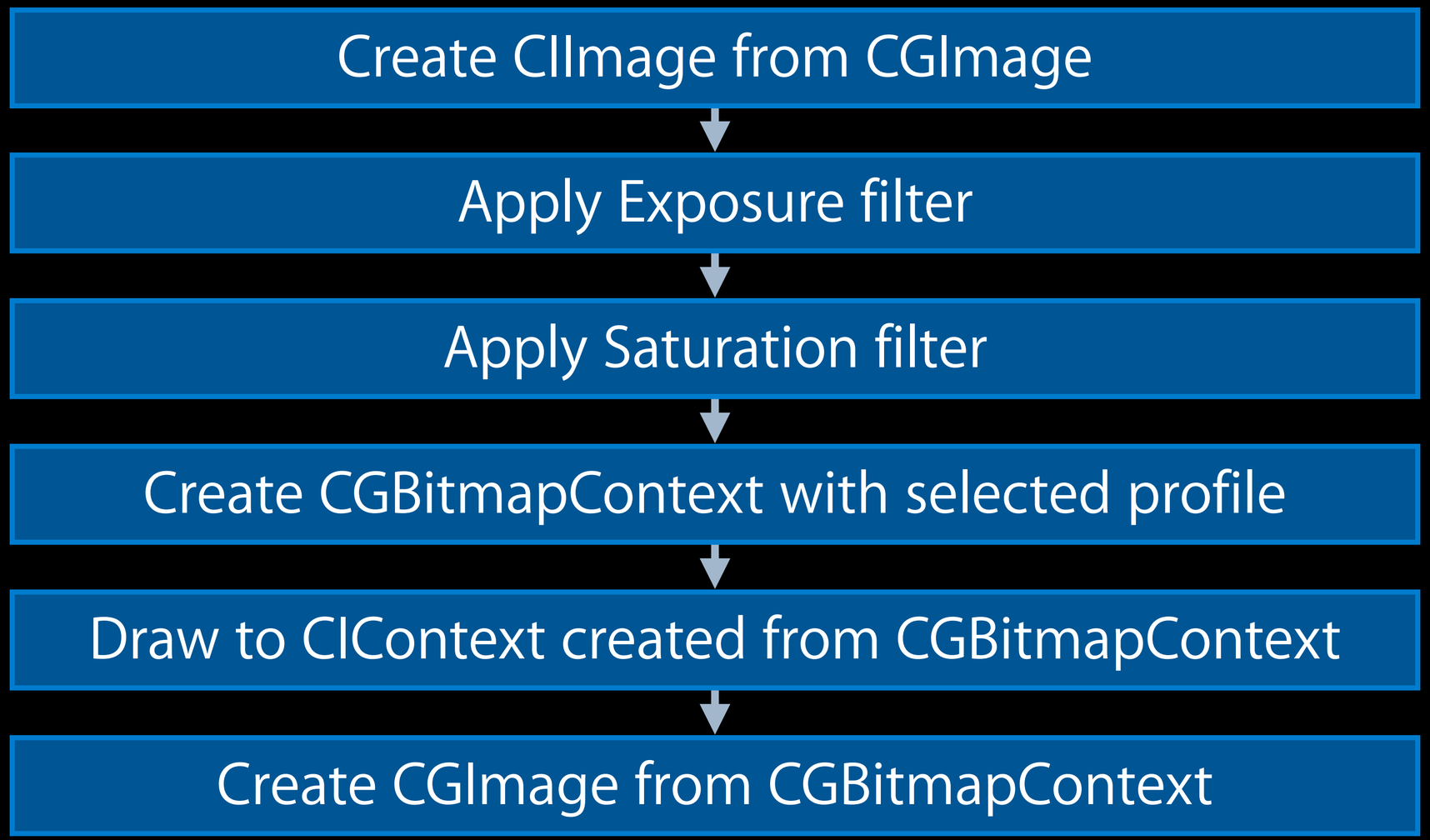
Filtering Images With Core Image

Drawing to a window and softproofing destination profile

```
- (void) drawCIImage
{
   CIImage* ciimg = [CIImage imageWithCGImage:mImage];

   ciimg = [self imageTransformToFitView: ciimg];
   ciimg = [self applyExposureAndSaturationFilters: ciimg];
   ciimg = [self applyColorCubeFilter: ciimg profile:mDestinationProfile];

   CGRect rect = [self centerInViewRect: [ciimg extent]];

   CGContextRef ctx = [[NSGraphicsContextcurrentContext] graphicsPort];

   CIContext* ciContext = [CIContext contextWithCGContext: ctx options:nil];

   [ciContext drawImage: ciimg inRect: rect fromRect: [ciimg extent]];
}
```

Filtering Images With Core Image

Creating a CGImage for printing or saving



Filtering Images With Core Image

Creating a CGImage for printing or saving as an image file

```
- (CGImageRef) createCGImage
{
   CIImage* ciimg = [CIImage imageWithCGImage:mImage];

   ciimg = [self applyExposureAndSaturationFilters: ciimg];

   CGContextRef bmCtx = [self bitmapContext:mDestinationProfile];

   CIContext* ciCtx = [CIContext contextWithCGContext: bmCtx options: nil];

   [ciCtx drawImage: ciimg inRect:mImageRect fromRect: [ciimg extent]];

   CGImageRef image = CGBitmapContextCreateImage(bmCtx);

   CGContextRelease(bmCtx);

   return image;
}
```

Printing Images

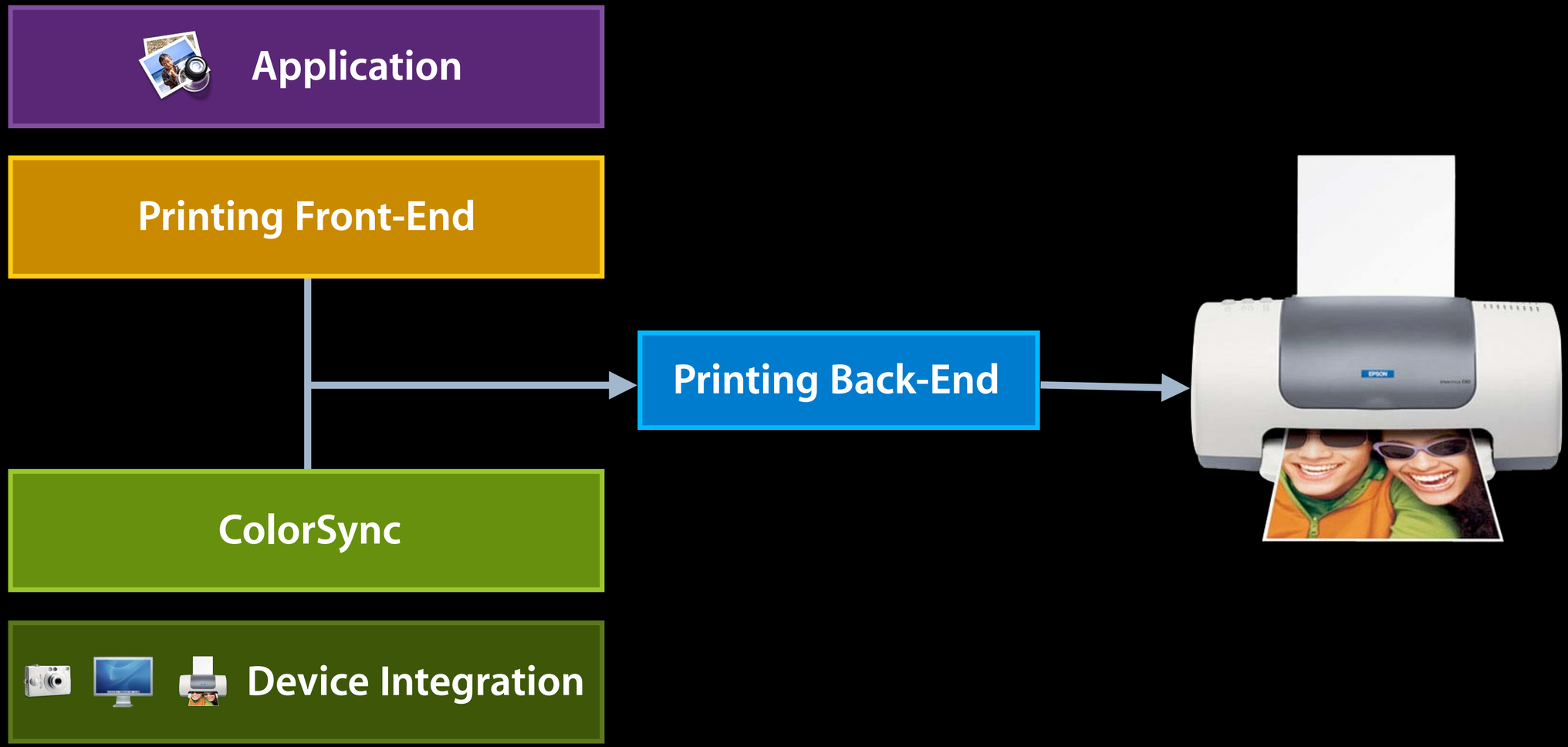
http://developer.apple.com/wwdc2005/

Printing Images

Basics

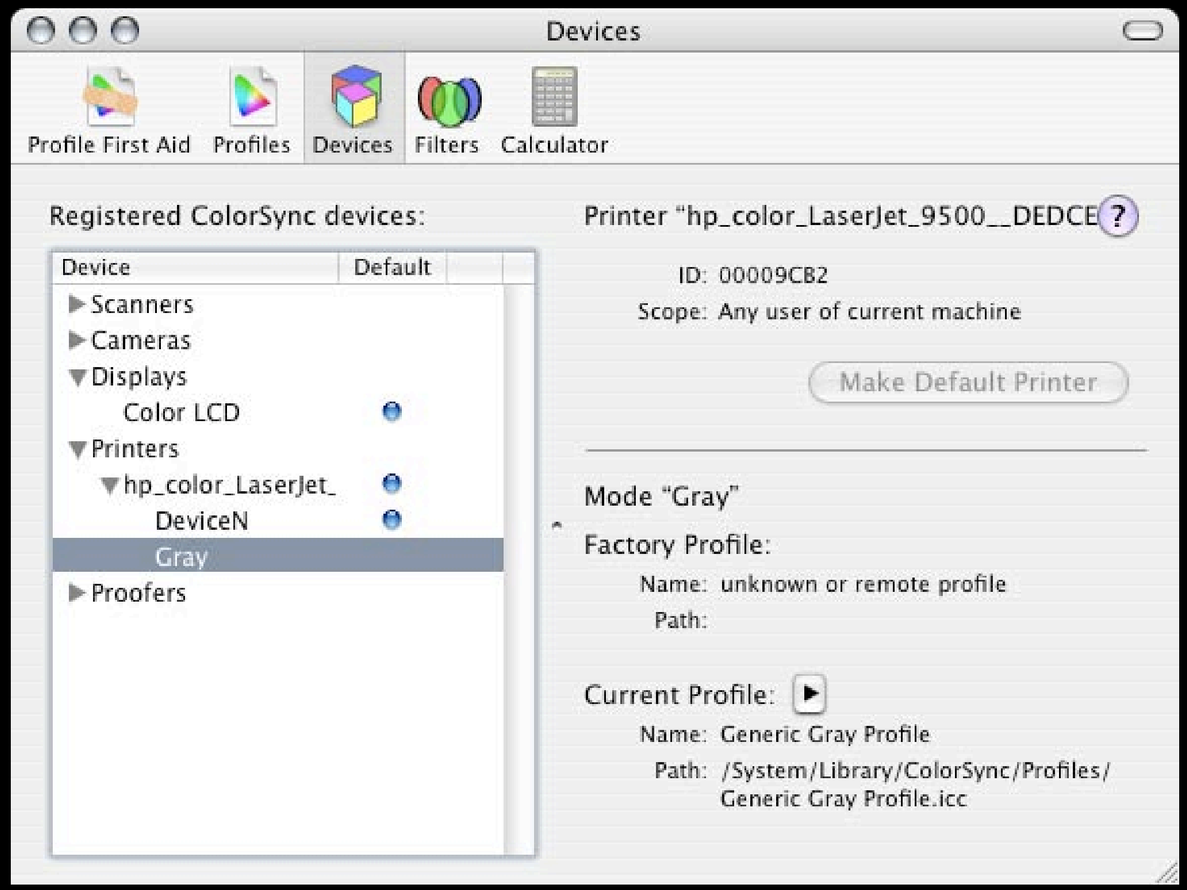
- Architecture overview
  - Printing as a part of Color Communication
- Application vs. Driver color management
- Controlling Printing Front-end
  - Preserving intended color information

Printing Architecture Overview



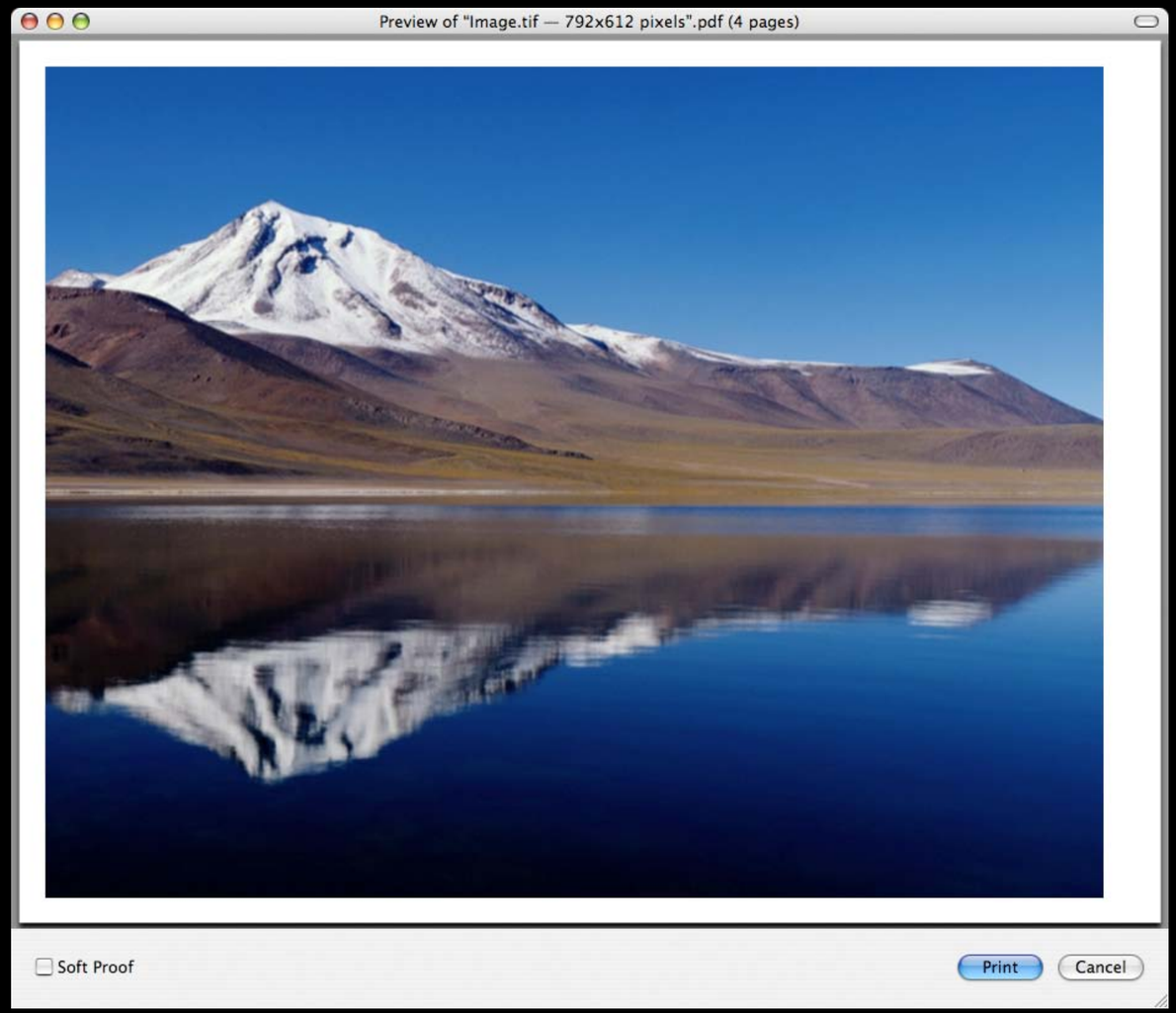
Printing Architecture Overview

Device integration database



Printing Images

Example of color communication based on ColorSync profiles



Printing Images

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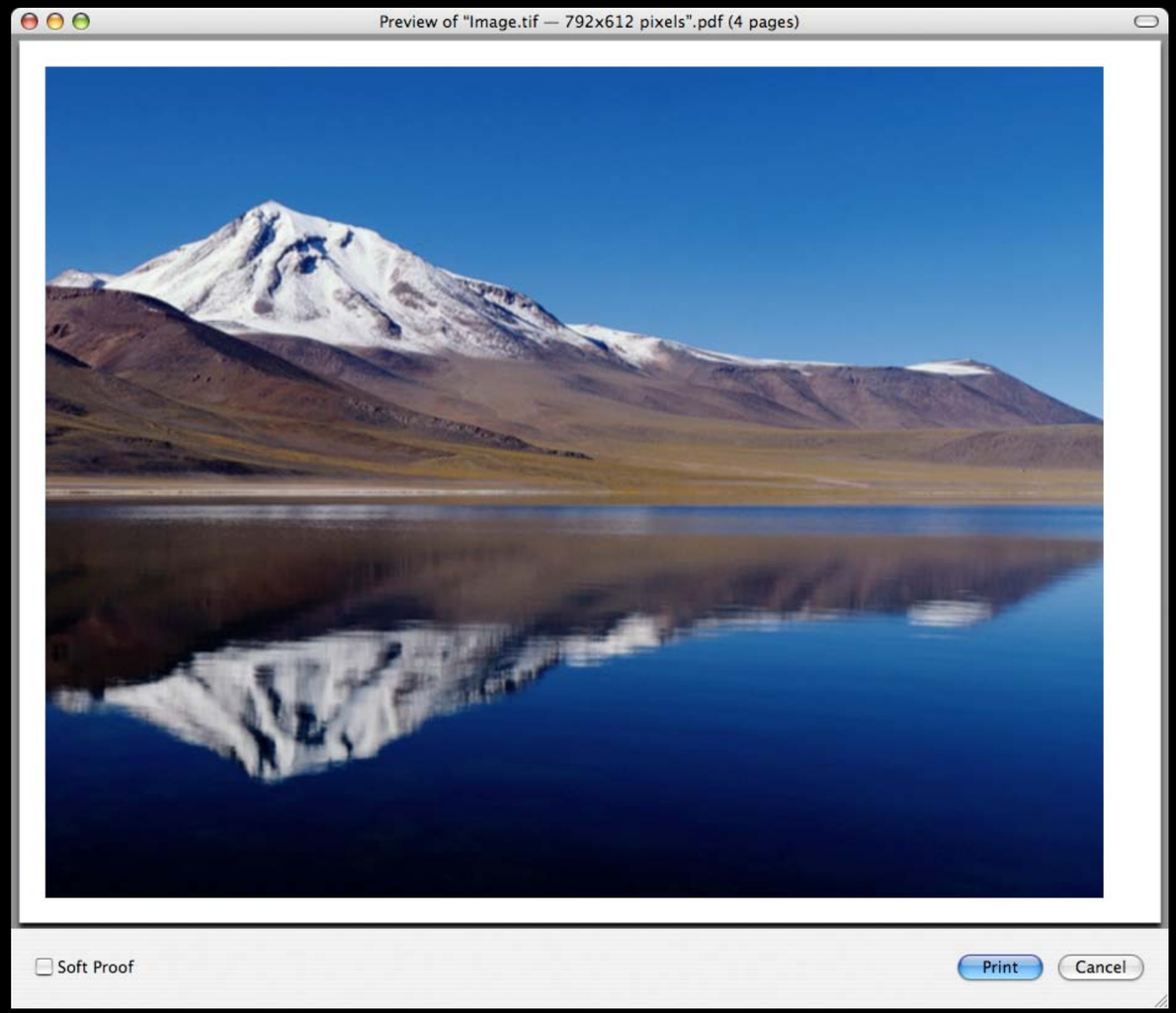
Printing Images

Example of color communication based on ColorSync profiles



Printing Images

Color Communication

- Requires
  - Application to spool calibrated color data
  - Known printer profile for current print mode
  - Driver to not do any additional color manipulation
- Benefits
  - Allows for softproof in print preview
  - Allows savvy application to produce output specific color
    - PDF/X Output Intent

Printing Images

Application vs. driver color management

- (Application) ColorSync mode
  - Printing is a part of Color Communication
    - Color data is matched to the printer profile registered with ColorSync
    - Driver does not make any color adjustment
- Driver mode
  - Printing is excluded from Color Communication
    - Color data is matched to a generic profile and handed off to the Driver
    - Driver makes color adjustments which are not communicated to the system

Printing Images

Controlling printing front-end

```
- (NSPrintOperation*)
   printOperationWithSettings:(NSDictionary*) printSettings
                        error: (NSError **) outError
{
   [self calculateMargins: printSettings];

   PrintView* printView = [[self createPrintView] autorelease];

   NSPrintOperation* printOp =
       [NSPrintOperation printOperationWithView:printView
                                      printInfo:[self printInfo]];

   if (outError) // Clear error.
       *outError = NULL;

   return printOp;
}
```

Printing Images

Controlling printing front-end (Cont.)

```
- (void) drawRect: (NSRect) rect
{
   CGContextRef context = [[NSGraphicsContext currentContext] graphicsPort];

   CGAffineTransform imTransform = [self imageTransform:im];

   CGContextSaveGState(context);

   CGContextConcatCTM(context, imTransform);

   CGContextDrawImage(context, imageRect, image);

   CGContextRestoreGState(context);

   CGImageRelease(image);
}
```

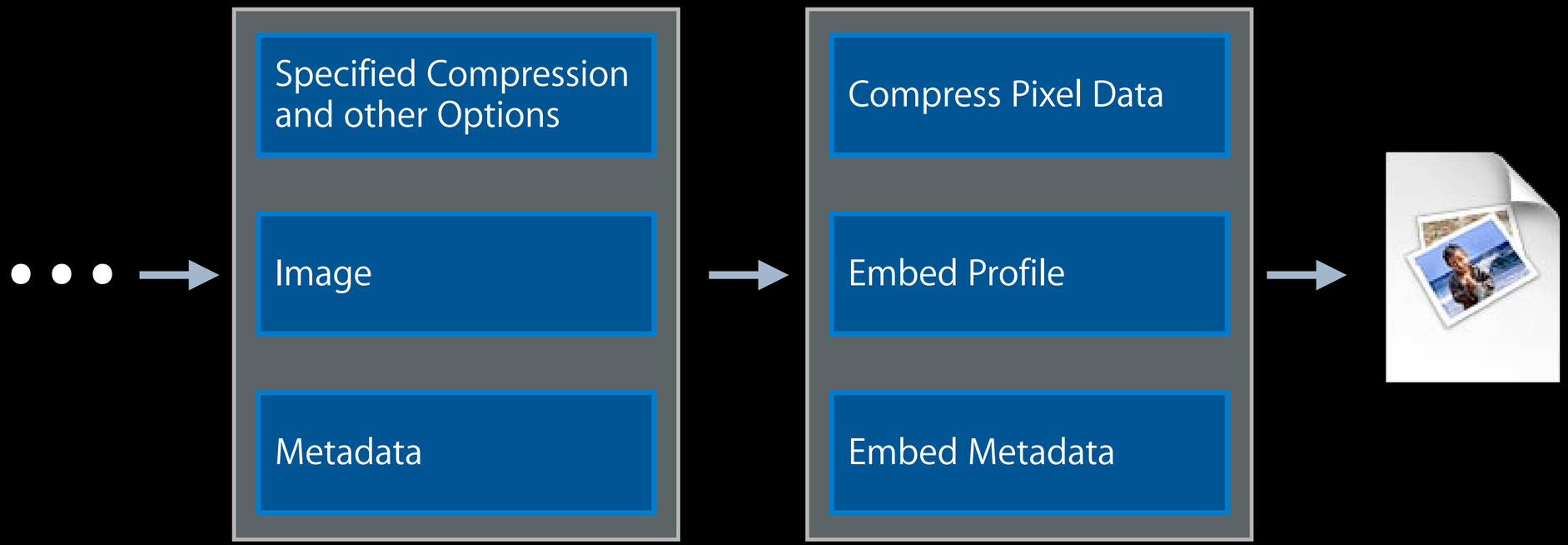
Saving Images With Image IO

David Hayward
Software Engineer

http://developer.apple.com/wwdc2005/

Saving Digital Images

General steps when saving an image



Saving Images With Image IO

CGImageDestination

- Create with
  - Use `CGImageDestinationCreateWithURL`
    or `CGImageDestinationCreateWithData`
    or `CGImageDestinationCreateWithDataConsumer`
  - Type identifier (file format)
  - Capacity (image count)
- Set properties for whole file: `CGImageDestinationSetProperties`
- Add each image with options and metadata: `CGImageDestinationAddImage`
- Finish by calling: `CGImageDestinationFinalize`

Saving Images With Image IO

CGImageDestination image and metadata

```
bool WriteJpegImage (CFURLRef url, CGImageRef image, float dpi)
{
   CGImageDestinationRef idst =
      CGImageDestinationCreateWithURL(url, CFSTR("public.jpeg"), 1, nil);

   CFStringRef keys[3]; CFNumberRef vals[3];

   keys[0] = kCGImageDestinationLossyCompressionQuality;
   vals[0] = CreateFloatNumber(0.80);

   keys[1] = kCGImagePropertyDPIWidth;   vals[1] = CreateFloatNumber(dpi);
   keys[2] = kCGImagePropertyDPIHeight;  vals[2] = CreateFloatNumber(dpi);

   CFDictionaryRef props = CFDictionaryCreate(nil, keys, values, 3,
      &kCFCopyStringDictionaryKeyCallBacks, &kCFTypeDictionaryValueCallBacks);

   CGImageDestinationAddImage(idst, image, props);
   return CGImageDestinationFinalize(idst);
}
```

Saving Images: Advanced Techniques

- Saving floating point images
- Adding save options to NSSavePanel

Saving Images: Advanced Techniques

Saving floating point images

- Just provide the `CGImageDestination` a `CGBitmap` with float pixels
- Currently only two file formats support writing float data
  - IEEE Float TIFF and OpenEXR

Saving Images: Advanced Techniques

Adding save options to NSSavePanel

- Start with options dictionary from original file
- Build file format pop-up from `CGImageDestinationCopyTypeIdentifiers`
- Use UI actions to store options and metadata into dictionary

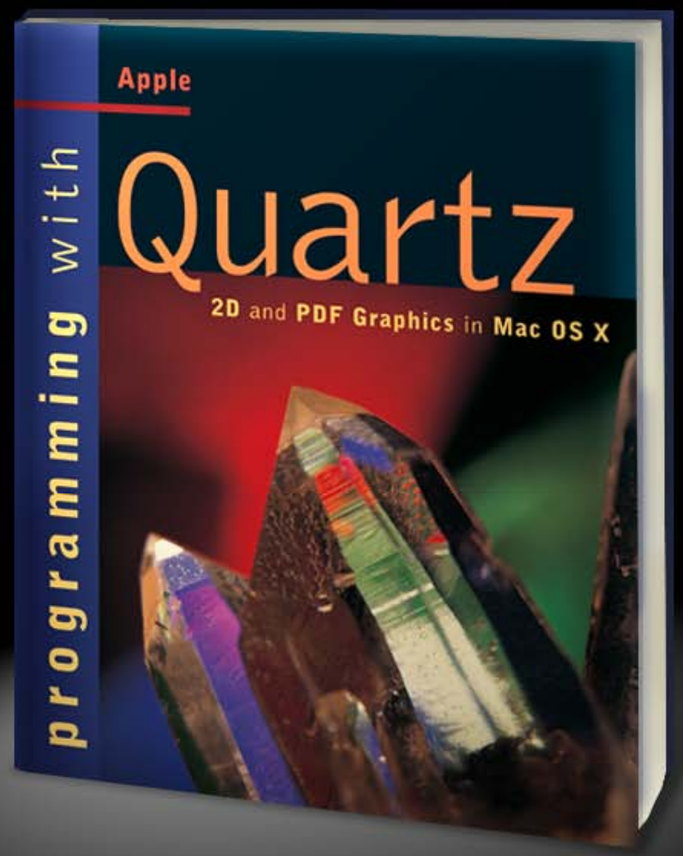
ImageApp Sample Code

http://developer.apple.com/wwdc2005/

Documentation, Sample Code, and Other Resources

http://developer.apple.com/wwdc2005/

Coming Soon From Morgan Kaufmann…



More info and sample chapter:
http://books.elsevier.com/mk/?isbn=0123694736

Related Sessions

Essential Ingredients for Mac OS X Imaging Solutions	Session 210 Wednesday 3:30PM
Printing Best Practices for Your Application	Session 212 Thursday 9:00AM
Core Image	Session 202 Tuesday 10:30AM
Optimal 2D Application Graphics	Session 216 Friday 10:30AM
Quartz 2D and PDF Kit	Lab Thursday 12–5:00PM

Q&A

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http://developer.apple.com/wwdc2005/

WWDC2005

Worldwide Developers Conference